B602

UNIVERSAL RF BRIDGE

OPERATING INSTRUCTIONS

WAYNE KERR

OPERATING INSTRUCTIONS

for

UNIVERSAL RF BRIDGE B602

THE WAYNE KERR COMPANY LIMITED

ROEBUCK ROAD CHESSINGTON SURREY ENGLAND

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INTRODUCTION

The B602 is an RF Bridge for the measurement of capacitance, conductance, resistance and inductance with an accuracy of 1% at frequencies between 100kHz and 3MHz or, with reduced accuracy, up to 10MHz. The instrument is a passive device and is used in conjunction with an external source and detector.

The bridge is based on the now familiar transformer ratio-arm principle but a novel feature in this case is the inclusion of an inductance standard. This, together with C and R Standards and phase reversing windings on the transformers, permits aperiodic measurements in all four quadrants of the complex plane.

This instrument also introduces a new concept in continuously variable precision voltage dividers that obviate the necessity for variable standards. The device makes use of the magnetic field in a single turn loop and, for this reason, is called a "MAGPOT".

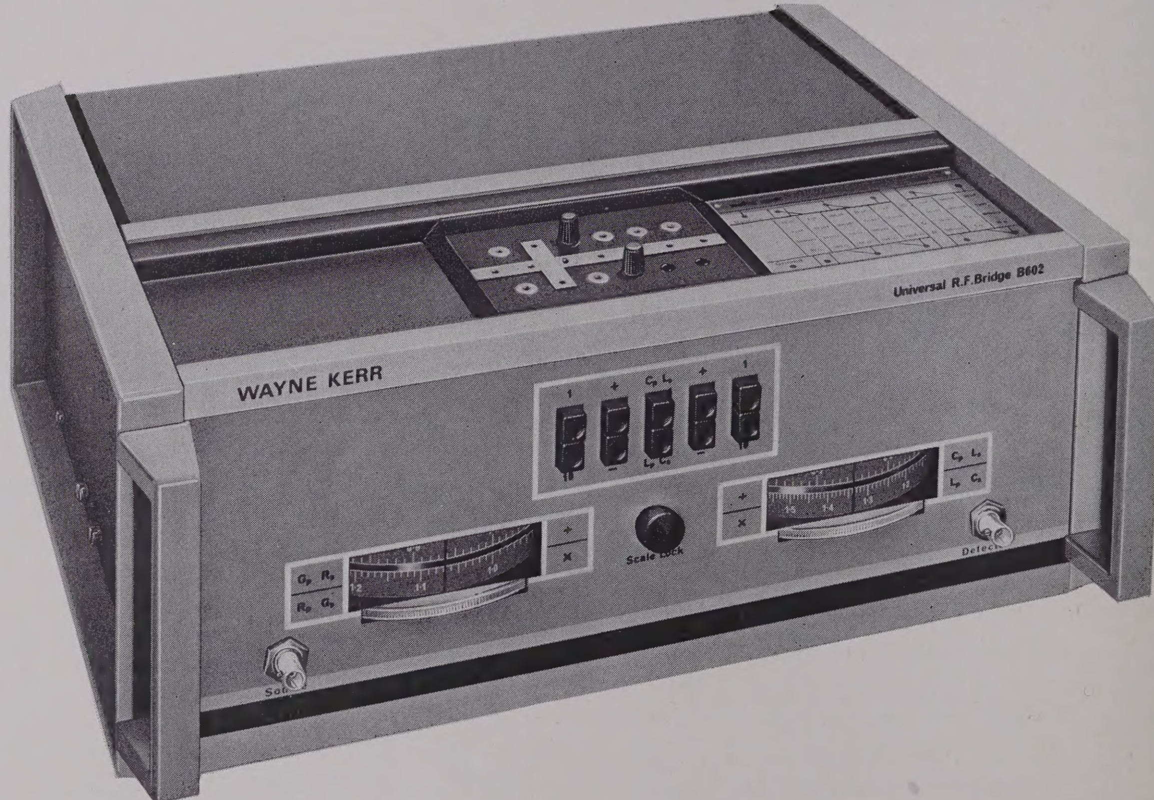
The arrangement of the bridge is such that on the five upper ranges the unknown is measured in terms of its parallel components, while on the lower three ranges the measurement is in terms of the series components.

Certain ancillary instruments and adaptors, described in separate publications, are available for use with the B602; they include the following:

SR268 Bridge Source and Detector, covering the frequency ranges 100kHz to 100MHz in nine bands. The instrument features ganged tuning of Source and Detector, separate attenuators for source output and detector input, visual null detection and it can be operated from either A.C. power line supplies or external batteries.

C602 Coaxial Adaptor permits the use of standard leads with BNC connectors. It also facilitates the use of external transfer standards (for example certain of the Wayne Kerr Q201 standards) for checking the performance of the B602.

The B602 can be supplied either for bench use or as a rack-mounted instrument.


WAYNE KERR
Universal R.F.Bridge B602
Scale Lock

SPECIFICATION

Frequency Range	100kHz – 10MHz
Measurement Ranges	Overall:
	1fF – 1mF (0.001pF–1000μF)
	100μΩ – 100MΩ
	10pH – 10H
	10n℧ – 10k℧

$\left.\begin{array}{l} \text{1fF – 1mF (0.001pF–1000μF)} \\ \text{100μΩ – 100MΩ} \\ \text{10pH – 10H} \\ \text{10n℧ – 10k℧} \end{array}\right\}$ + or –

Accuracy (%)

				up to 3MHz	up to 5MHz	up to 10MHz
C	Shunt	1pF	– 10nF*	1	2	5
	Series	10nF	– 1μF†	2	2	5
R	Shunt	10Ω	– 100kΩ	1	2	5
	Series	100mΩ	– 10Ω	2	2	5
L	Shunt	1μH	– 10mH	1	3	5
	Series	10nH	– 1μH§	2	3	5

*Frequency limited to give reactance $\not<$ 10Ω
†Frequency limited, depending on series inductance.
§Frequency limited, depending on self-capacitance of inductor.

Discrimination

(a) Linear Scales	0.1% of full range capability. One division of these scales represents 1% of full range capability.
(b) Reciprocal Scales	0.1% of scale indication. Where a reciprocal scale reading is above 20 it is advisable, where possible, to use the next higher range. If a minor term is being read and the other dial is in full use, then range changing is not possible but, by depressing the 10 button, greater discrimination of the minor term reading can be achieved.
Source/Detector	Wayne Kerr model SR268 (100kHz–100MHz). Detector sensitivity required for 0.1% discrimination of L, C and R at 1.592MHz for 1V r.m.s. into bridge = 0.3μV. Input and output impedances: approx. 75Ω.
Dimensions (B602)	Width 445 mm (17.5 in.) Height 165 mm (6.5 in.) Depth 345 mm (13.5 in.)
Weight	Approx. 11 kg. (24 lb.)

ANCILLARY ITEMS

Source/Detector Leads	D10109/2 (2 off) Accessories (comprising terminals, link, clip lead and Neutral screen).

OPERATING INSTRUCTIONS

PREPARATION FOR USE

Being a passive instrument, the B602 requires an external source and detector. The most satisfactory results will be obtained when the B602 is used in conjunction with the Wayne Kerr Source and Detector SR268. The SR268 is recommended because it embodies ganged tuning of the source and detector over the full range of frequencies applicable to the B602. Furthermore, being designed as complementary instruments, they stand conveniently together and have terminals arranged for short and direct interconnections. The operating controls for input level and output sensitivity on SR268, and for bridge balancing on B602, fall naturally to hand so that extended periods of operation can be maintained without fatigue. If an alternative source and detector are to be used, the source should provide not less than 2V r.m.s. into 75Ω while the detector sensitivity should be better than 0.3μV with 75Ω input impedance. The Wayne Kerr Video Oscillator type O200 is a suitable source and most communication receivers can be used as the detector.

The source and detector should be well screened, both from each other and from the unknown impedance, since any direct coupling between them will cause a false trim. With the detector at maximum sensitivity, there should be no measurable signal when the detector plug is withdrawn from its socket on the bridge and its outer is connected to the outer of the source input connector. When the source and detector are separate units, it may be necessary to connect together the outers of the Source and Detector BNC connectors on the B602.

CONNECTION OF THE UNKNOWN

The Unknown admittance is connected between a pair of terminals screwed into the appropriate holes on top of the instrument according to the approximate magnitude of its major term. The plate to the right-hand side of the terminals gives the full scale value (or equivalent value of unity on the top linear scales) for C, G, L and R. The diagonal lines indicate the full scale values when the terminals so joined are used.

Commencing at the left (as viewed from the front), the function of the terminals is as follows:

> The single terminal at the extreme left facilitates connection to the Neutral bar between the two rows of terminals. For some measure-

ments this terminal must be connected to ground at the front terminal of the first pair from the left; a shaped plate is provided for making this connection. The other terminal of this pair is a single-turn "reverse" winding the purpose of which is explained later.

The next three pairs of terminals from the left are the connections for the 'parallel bridge'. The last two pairs of connectors are the 'series bridge' and are used for low impedance measurements. Note that the front connection in both of these pairs is not a screw terminal but a miniature single-pole socket, into which is connected the miniature crocodile clip lead. In the five pairs of bridge terminals, those to the rear are the source or voltage connections while those nearest to the front panel are the detector or current connections.

The channel-shaped bar supplied with the accessories is a screen for reducing the capacitance between the rows of terminals. This screen assists in maintaining the bridge trim and it should be fitted in place for all measurements except those involving the use of a jig or when its presence would hinder the connection of the test component.

When the Unknown cannot be directly connected to the terminals, standard bridge measurement leads (Type D10065) or low capacity leads (Type D10642B) can be used by means of the Coaxial Adaptor Type C602 (not advised on the lowest impedance range).

SIGN AND MULTIPLIER SWITCHES

The push-button switch block on the front panel facilitates the selection of sign and multiplier for L/C and G/R functions. Selection of the capacitance (C) or inductance (L) standard is made by operation of the central pair of buttons. Note that parallel inductance (Lp) and series capacitance (Cs) measurements are covered by the lower button while the upper button covers parallel capacitance (Cp) and series inductance (Ls) measurements. In general, the most accurate results are obtained when the Unknown is connected to terminals chosen so that the multiplier $\times 1$ is in use. When a $\times 10$ button is operated, scale indications are multiplied by ten for parallel R and L or series G and C but divided by ten for parallel G and C or series R and L. For convenience of reference, these combinations are indicated on the front panel adjacent to the scale apertures.

For most measurements the '+' sign buttons will be operated but cases may arise where the use

of the '—' sign is advantageous, e.g. the additional or alternative measurement of inductance as negative capacitance.

TYPES OF MEASUREMENT

Before the bridge is trimmed, the appropriate ground and neutral connections must be made according to the type of measurement required. These are as follows:

Parallel Measurements

(a) Small components connected directly to the bridge terminals. Ground and Neutral connected together (Fig. 1).

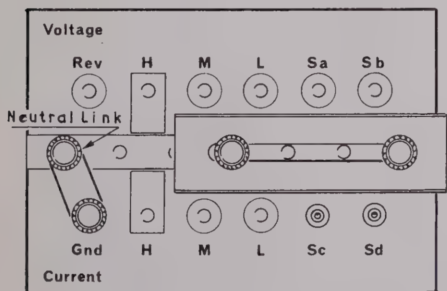


Fig. 1 Neutral Screen and Link arrangement

(b) Balanced impedances isolated from ground. Ground and Neutral not linked (Fig. 2.)

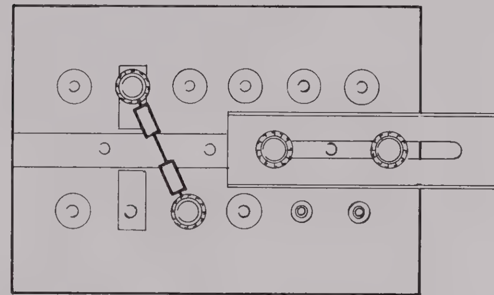


Fig. 2 Balanced Impedances (Floating)

(c) Balanced impedances with centre point to ground. Ground terminal to centre-point of Unknown; Neutral left free (Fig. 3).

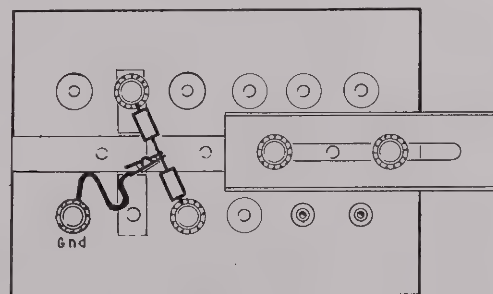


Fig. 3 Balanced Impedances (Grounded)

This type of measurement is restricted to the 10Ω and 100Ω ranges; accuracy ±2%.

(d) Unbalanced impedances. Ground terminal to ground of Unknown; Neutral left free.

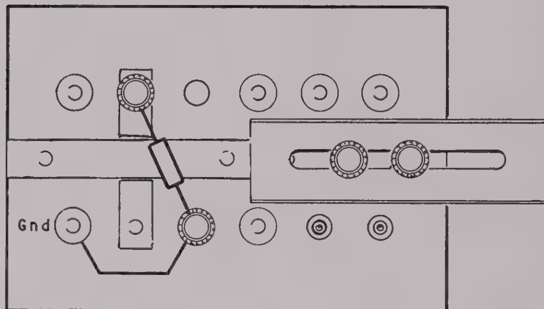


Fig. 4 Unbalanced Impedances (Grounded)

Measurements are then made in the normal manner, except that terminal H, M or L (see Figs. 1 and 4) will be grounded.

(e) Screened connecting leads. If screened leads are used to connect the Unknown to the bridge terminals (not necessary on lowest impedance range), the screens should be joined at the bridge end and connected to Neutral. Provided that the series impedance of the leads can be neglected, the only effective impedance is that of the Unknown.

(f) In-Situ measurements. The arm of the network containing the component to be measured should be connected to the bridge terminals. The shunting effects of associated components can in most cases be eliminated by connecting together the remote ends of these components and taking them to Neutral.

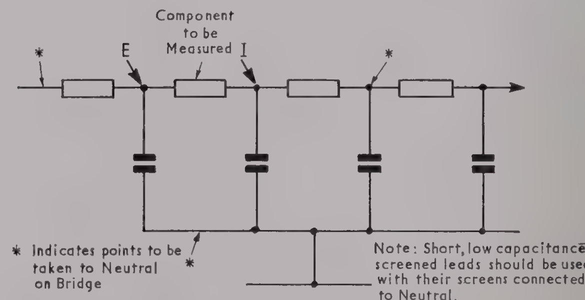


Fig. 5 Measurement of Components In-situ

NOTE: When measurements are made with the bridge Neutral not connected to Ground, the available range is restricted as detailed in the Specification. This restric-

tion is partly due to a falling off of the trim range at higher frequencies and this can be overcome to some extent by using the Reverse terminal as detailed under "Use of the Reverse Terminal" (page 20).

Series Measurements

Such measurements are limited to those in which the Neutral bar is connected to Ground and also to the measurement of components that can be connected directly to the terminal block.

INITIAL TRIMMING (PARALLEL MEASUREMENTS)

(1) Connect the Source and Detector and tune to the required frequency. Ideally, the bridge should be trimmed at the frequency of operation but, if the trimming is done at 1MHz it will generally hold good between the frequencies 300kHz and 3MHz. For the greatest accuracy the trim should be checked before making the measurement.

(2) Remove any components connected to the bridge measurement terminals.

(3) Using the link provided, connect the Ground and Neutral terminals in accordance with the section Types of Measurement. If an adaptor, jig or screened leads are to be used these should be in place.

Press the appropriate sign, multiplier and Cp or Lp buttons.

(4) Set the two main controls to zero (discounting the 10% scale overlap).

Turn the Scale Lock control clockwise until both scale drums are locked. A slipping clutch allows the thumbwheel controls to be turned independently of the scale drums.

(5) If the Source and Detector SR268 is being used, refer to the Operating Instructions for that instrument.

If any other source and detector are being used, increase the source output level and detector sensitivity slowly from zero until approximately mid-scale deflection is obtained on the detector indicating meter.

(6) With the two main scale drums locked at zero, adjust the thumbwheel controls sequentially for minimum detector output, repeating as necessary. Increase the Source output and/or Detector sensitivity as necessary to obtain better balance discrimination and readjust the two thumbwheels as necessary until the final balance condition is achieved.

(7) Release the Scale Lock control, ensuring that the knob is in the fully counter-clockwise position.

COMPONENT MEASUREMENT (PARALLEL)

Where the approximate value of the component is known, proceed as follows:

(1) Connect the component or admittance to be measured.

(2) Balance the bridge with both thumbwheel controls in turn, taking the most significant in each case first.

(3) Reference to the equivalent value of unity for each scale (as given on the plaque to the right of the terminal block), will give the values of G or R and L or C as appropriate.

Where the approximate value of a component is not known, use the following procedures:

Resistance

(1) Press the Cp Ls button. Ensure that the conditions of measurement are as specified in the section "Types of Measurement". Trim the bridge as for parallel measurements.

(2) Connect the component to be measured to Range 4 (see Fig. 7), balance the bridge in the normal way and note the reading on the Rp Gs scale.

(3) If balance occurs between 10 and 100 on this scale, then the component should be measured on Range 5 for most accurate results.

(4) If balance on Range 4 occurs just above 100 on the Rp Gs scale then the measurement should be made on Range 6.

(5) Where a reading closer to infinity is obtained on Range 4, Range 7 or 8 must be used.

(6) If a balance cannot be obtained, implying that the component is of low impedance, use the Series Ranges as detailed on page 13.

NOTE: In general, the most accurate results are obtained when the Unknown is connec-

ted to terminals chosen so that the multiplier $\times 1$ is in use. When a 10 button is operated, scale indications are multiplied by ten for parallel R and L or series G and C but divided by 10 for parallel G and C or series R and L; these combinations are indicated on the front panel adjacent to the scale apertures.

Capacitance

(1) Ensure that the conditions of measurement are as specified in the section "Types of Measurement", depress the Cp Ls button, then trim the bridge as for parallel measurements.

(2) Connect the component to Range 4, balance the bridge and note the reading on the Cp Ls scale.

(3) If the reading is just below 0.1 use Range 5 for the measurement. If the reading is just below 0.01 use Range 6 and if the reading is close to zero, use Range 7 or 8.

(4) If a balance cannot be obtained, implying that the component is of low impedance, carry out the measurement on the Series ranges.

Inductance

(1) Ensure that the conditions of measurement are as specified in the section "Types of Measurement" on page 9. Press the Lp Cs button and trim the bridge in the normal way.

(2) Connect the component to be measured to Range 4. If the reading on the Lp Cs scale is between 10 and 100, the measurement should be made on Range 5.
If the reading is just above 100 use Range 6 and if the reading is closer to infinity use Ranges 7 or 8.

(3) Where balance is unobtainable, the component must be measured on the Series (low impedance) ranges as detailed on page 13.

INITIAL TRIMMING (SERIES MEASUREMENTS)

(1) Connect the Source and Detector and tune to the required frequency. Ideally, the bridge should be trimmed at the frequency of operation but, if the trimming is done at 1MHz it will generally hold good between the frequencies 300 kHz and 3 MHz. For the greatest accuracy the trim should be checked before making the measurement.

(2) Connect the component to be measured between the Neutral bar and the appropriate terminal in the rear row. Use Range 3 for trimming if component value is not known approximately, and re-trim when the correct range of measurement has been determined as detailed under Component Measurement (Series). Insert the miniature clip lead plug into the socket appropriate to the measurement range required.

(3) Attach the clip to the component lead connected to the Neutral bar.

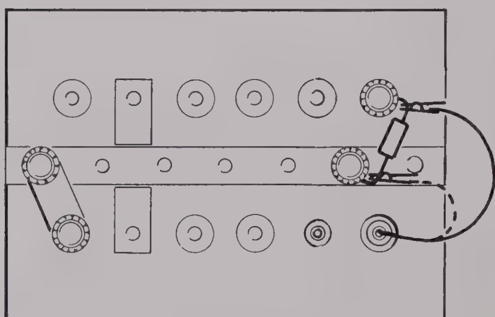


Fig. 6 Component Measurement (Series)

It should be connected as close to the body of the component as possible unless the component leads are to be included in the measurement. It follows that if the lead impedance forms a significant part of the impedance being measured, this can be included in the measurement by connecting the clip to the appropriate point.

(4) Using the link provided, connect the Ground and Neutral terminals in accordance with the section "Types of Measurement". If an adaptor, jig or screened leads are to be used these should be in place. Press the appropriate sign, multiplier and Cs or Ls buttons.

(5) Set the two main controls to zero (discounting the 10% scale overlap). Turn the scale lock control clockwise until both scale drums are locked; a slipping clutch allows the thumbwheel controls to be turned independently of the scale drums.

(6) If the Source and Detector SR268 is being used, refer to the Operating Instructions for that instrument. If any other source and detector are being used, increase the source

output level and detector sensitivity slowly from zero until approximately mid-scale deflection is obtained on the detector indicating meter.

(7) With the two main scale drums locked at zero, adjust the thumbwheel controls sequentially for minimum detector output, repeating as necessary. Increase the source output and/or detector sensitivity as necessary to obtain better balance discrimination and readjust the two thumbwheels as necessary until the final balance condition is achieved.
Release the Scale Lock control, ensuring that the knob is in the fully counter-clockwise position.

COMPONENT MEASUREMENT (SERIES)

Where the component value is known approximately, proceed as follows:

With the trim procedure completed, transfer the miniature clip to the other side of the component body, bearing in mind that the component lead impedance can be included in the measurement if so desired. Balance the bridge and note the scale indications.

Where component values are not known, the following procedure should be adopted.

Resistance

Trim the bridge in the normal manner. Connect the component to be measured to Range 3 and balance the bridge.

If the reading on the Gp Rs scale is just below 0.1, carry out the measurement on Range 2. If the reading is less than 0.01 on the scale, make the measurement on Range 1 (See Fig. 7). For maximum accuracy the bridge should be re-trimmed with the component connected to the correct range.

Capacitance

Depress the Lp Cs button and trim the bridge in the normal manner, but without the unknown connected.

Connect the component to be measured to Range 3 (see Fig. 7) and balance the bridge. If the reading on the Lp Cs scale is between 10 and 100, carry out the measurement on Range 2. If the reading is between 100 and infinity use Range 1. The bridge should be re-trimmed on the final range selected to obtain maximum accuracy.

Inductance

Press the Cp Ls button and trim the bridge in the normal manner. Connect the component to be measured to Range 3, balance the bridge and note the reading on the Cp Ls scale. If the reading is between 0.1 and 0.01 use Range 2 and if the reading is between 0.01 and 0 use Range 1. The bridge should be re-trimmed on the final range selected to obtain maximum accuracy.

INTERPRETATION OF RESULTS

On both scale drums the lower scale is calibrated as the reciprocal of the upper scale. Note that the '10' buttons, if operated, are either multipliers or dividers according to the readout scale used—see the section "Sign and Multiplier Switches".

The multiplier buttons operate independently of one another. The value of unity for both scale drums and for each range is given on the plaque to the right of the terminal block. For convenience the plaque is reproduced in Fig. 7, together with a Bridge accuracy table given in Table 1.

When the bridge is balanced, the two scale indications give values for the Unknown in terms of the series components of in-phase and quadrature terms on Ranges 1, 2 and 3.

On Ranges 4–8 inclusive, the scale indications

BRIDGE ACCURACY		
	PARALLEL	SERIES
100kHz– 3MHz	±1%	±2%*
3MHz– 5MHz	±2% (±3% on L)	±3%*
5MHz–10MHz	±5%	±5%*

*See "Measurement Accuracy" (Series Bridge)

Table 1 Bridge Accuracy

give the equivalent parallel values of the in-phase and quadrature terms. Either form can be readily converted to the other by means of the following formulae:

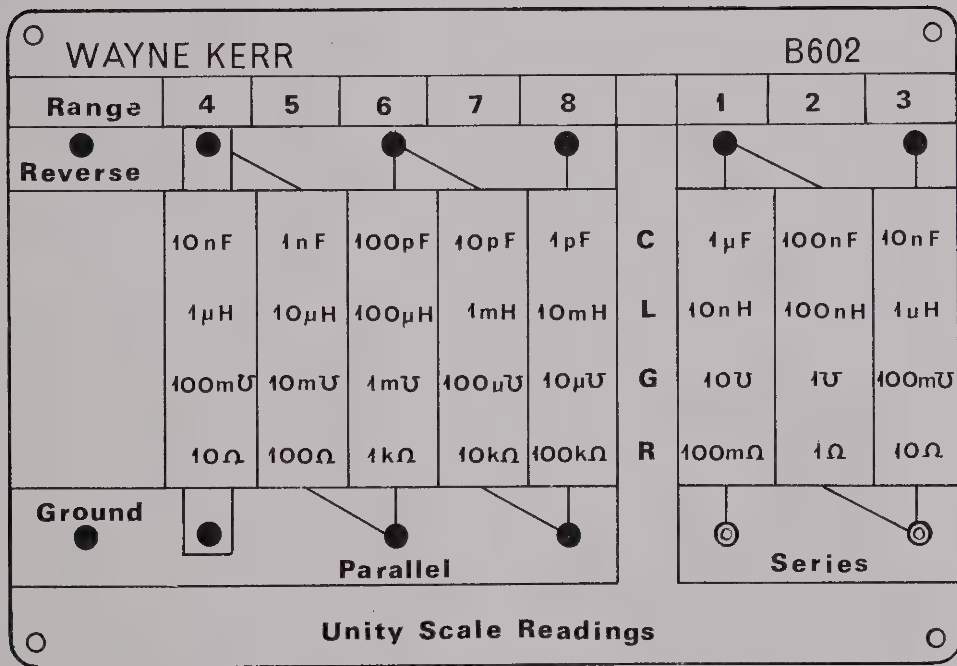


Fig. 7 Range Plate with Range Numbers added.

$$\left.\begin{aligned} Rs &= Rp/(1+Q^2) \\ Gs &= Gp\,(1+Q^2) \\ Cs &= Cp\left(1+\frac{1}{Q^2}\right) \\ Ls &= Lp\Big/\left(1+\frac{1}{Q^2}\right) \end{aligned}\right\} \quad \begin{aligned} &(\text{at } 1.592\text{MHz, } 2\pi f = 10^7) \\ &\text{where } Q = \frac{Rp}{\omega Lp} \\ &\text{or } Q = \omega Cp\,Rp \end{aligned}$$

$$\left.\begin{aligned} Rp &= Rs\,(1+Q^2) \\ Gp &= Gs/(1+Q^2) \\ Cp &= Cs\Big/\left(1+\frac{1}{Q^2}\right) \\ Lp &= Ls\left(1+\frac{1}{Q^2}\right) \end{aligned}\right\} \quad \begin{aligned} &\text{where } Q = \frac{\omega Ls}{Rs} \\ &\text{or } Q = \frac{1}{\omega Cs\,Rs} \end{aligned}$$

At 1.592MHz, Q is equal to the ratio of the numerical indication of the Cp scale to that of the Gp scale regardless of the Range in use. For example, if balance is obtained when the Cp scale indicates 0.8 and the Gp scale indicates 0.4, then Q = 0.8/0.4 = 2.

However, if one of the '10' (multiplier) buttons is operated then the appropriate scale indication must be divided by ten before computing Q. At other frequencies, Q is equal to the same ratio but multiplied by $\omega/10^7$.

MEASUREMENT ACCURACY (SERIES BRIDGE)

The Bridge Accuracy for series measurements given in the table on page 16 does not take account of a systematic error inherent in the measurement method used. (See Appendix). The systematic error applicable to each of the low impedance ranges is given in Fig. 8.

To correct for this systematic error the measured value should be multiplied by the appropriate factor given below.

$$\text{True Rs} = \text{Measured Value Rm} \times \{1 + [(R1+R2)\times Rm/R1.\,R2]\}$$

$$\text{True Ls} = \text{Measured Value} \times \{1+[(R1+R2)\times Rs/R1.\,R2] - [(R1+R2)\times X_{LS}/R1.\,R2]^2\}$$

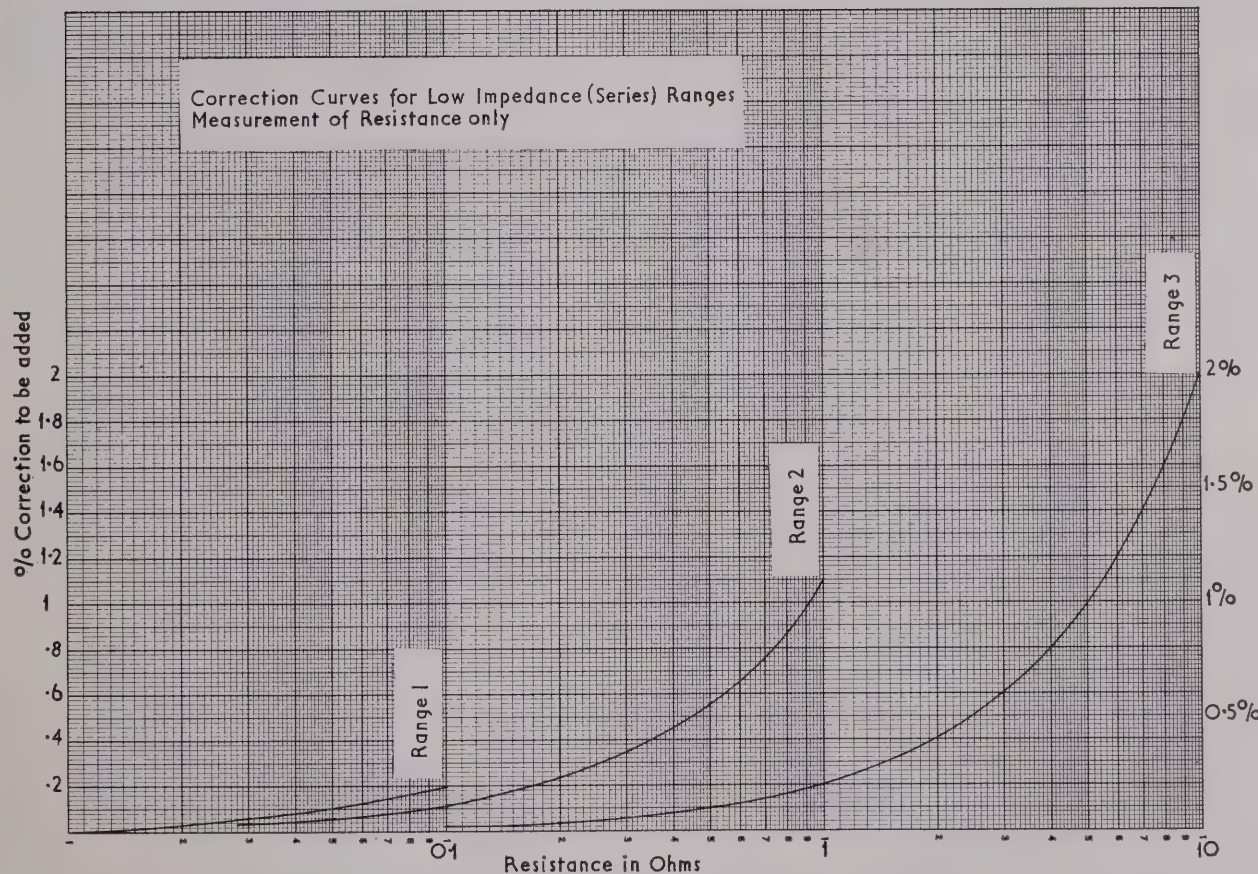


Fig. 8 Systematic Error Correction Curves

$$\text{True } C_s = \text{Measured Value} \times 1/\left\{1+[(R1+R2)\times R_s/R1.\ R2]-[(R1+R2)\times X_{CS}/R1.\ R2]^2\right\}$$

where on

Range 1 R1 = 100Ω	R2 = 100Ω
Range 2 R1 = 100Ω	R2 = 1kΩ
Range 3 R1 = 1kΩ	R2 = 1kΩ

USE OF REVERSE TERMINAL

The purpose of the Reverse terminal is to facilitate the connection of external components into the Standard side of the Bridge (parallel measurements only). The reason for doing this is that in some measurements, those involving the use of jigs, for example, it becomes necessary to extend the trim range of the bridge. The normal trim range is approximately ±15% of the range in use; this is adequate for normal use but, on the low capacitance ranges, the self capacitance of a jig may be greater than the trim coverage for these ranges. If, when a jig is used, it is found impossible to trim the bridge, proceed as follows:

(1) Remove the jig and trim the bridge in the normal way.

(2) Fit the jig in place, with the connections to the bridge made but no component connected.

(3) Balance the bridge and note the capacitance of the jig (it is assumed that the jig capacitance only will be outside the trim range). The capacitance value thus obtained must be neutralised (or trimmed out).

(4) Select a capacitor of the nearest preferred value to that obtained in (3).

(5) If the jig capacitance is within the limits of Range 7, the neutralizing capacitor must be connected between the Reverse Terminal and the Current Terminal of Range 7 (i.e. fourth from the left—front row). If measurement is on Range 6, then connect between Reverse and Range 6 Current Terminal.

(6) With the bridge scales set to 0 and the jig connected, it should now be possible to trim the bridge by following the normal procedure. If more convenient, a small variable capacitor can be used as the neutralizing component. This should be connected between the terminals as described in (5). With the jig in place and the bridge scales at 0, adjust the variable capacitor until balance is obtained. Check the bridge trim by the normal procedure.

The component thus connected takes no further part in the measurement and can be ignored. The above arrangement should hold good for a particular jig on any Range of the bridge but, depend-

ing on the material and construction of the jig, it may not hold good over the full frequency range; as previously recommended, the trim should be checked when the frequency is changed.

APPENDIX

SYSTEMATIC ERROR IN LOW IMPEDANCE MEASUREMENTS

When it is required to measure impedance values below 10Ω, the normal method of measurement becomes impracticable owing to the uncertainty of lead and contact resistances. For the precise measurement of such low impedances a different technique is adopted.

In the normal bridge arrangement, a standard voltage is applied to the unknown and the resulting current is compared with that in a standard impedance. For low values of unknown impedance, i.e. on Ranges 1 to 3 (Low Impedance), the bridge configuration is re-arranged so that Z_u is the shunt element in a T-network (see Fig. 9). If the series elements are made sufficiently large compared with the unknown, the source side of the bridge can be considered as a constant current generator while the detector side functions as a voltmeter. This technique is analysed in Wayne Kerr Monograph No. 1.

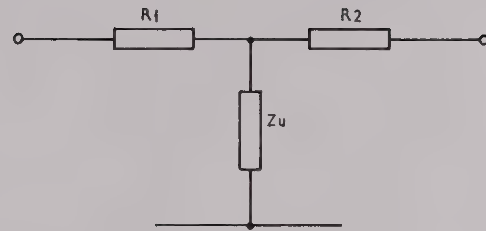


Fig. 9 Measurement Configuration (Series Bridge)

In practice, the series elements (R1 and R2) are made 100 times greater than the range maximum. This factor would normally give rise to a systematic error of 2%.

Though it was stated above that the source side of the Bridge can be considered as a constant current generator, it will be appreciated that this is strictly so only if the impedance of Z_u is zero; similarly, the loading on the detector is negligible only when Z_u is small compared with the detector input impedance. Since the value of R1 is 1kΩ (on Range 3) and the impedance of Z_u can vary between 0 and 10Ω, the maximum error would be 1%; also, since the input impedance of the detector R2 is 1kΩ (on Range 3), a further 1% error occurs when the impedance of Z_u is 10Ω.

RECIPROCAL TABLES

Note: Numbers in difference columns to be subtracted, NOT added.

	0	1	2	3	4	5	6	7	8	9
1·0	1·00000	99010	98039	97087	96154	95238	94340	93458	92593	91743
1·1	90909	90090	89286	88496	87719	86957	86207	85470	84746	84034
1·2	83333	82645	81967	81301	80645	80000	79365	78740	78125	77519
1·3	76923	76336	75758	75188	74627	74074	73529	72993	72464	71942
1·4	71429	70922	70423	69930	69444	68966	68493	68027	67568	67114
1·5	66667	66225	65789	65359	64935	64516	64103	63694	63291	62893
1·6	62500	62112	61728	61350	60976	60606	60241	59880	59524	59172
1·7	58824	58480	58140	57803	57471	57143	56818	56497	56180	55866
1·8	55556	55249	54945	54645	54348	54054	53763	53476	53191	52910
1·9	52632	52356	52083	51813	51546	51282	51020	50761	50505	50251
2·0	50000	49751	49505	49261	49020	48780	48544	48309	48077	47847
2·1	47619	47393	47170	46948	46729	46512	46296	46083	45872	45662
2·2	45455	45249	45045	44843	44643	44444	44248	44053	43860	43668
2·3	43478	43290	43103	42918	42735	42553	42373	42194	42017	41841
2·4	41667	41494	41322	41152	40984	40816	40650	40486	40323	40161
2·5	40000	39841	39683	39526	39370	39216	39063	38911	38760	38610
2·6	38462	38314	38168	38023	37879	37736	37594	37453	37313	37175
2·7	37037	36900	36765	36630	36496	36364	36232	36101	35971	35842
2·8	35714	35587	35461	35336	35211	35088	34965	34843	34722	34602
2·9	34483	34364	34247	34130	34014	33898	33784	33670	33557	33445
3·0	33333	33223	33113	33003	32895	32787	32680	32573	32468	32362
3·1	32258	32154	32051	31949	31847	31746	31646	31546	31447	31348
3·2	31250	31153	31056	30960	30864	30769	30675	30581	30488	30395
3·3	30303	30211	30120	30030	29940	29851	29762	29674	29586	29499
3·4	29412	29326	29240	29155	29070	28986	28902	28818	28736	28653
3·5	28571	28490	28409	28329	28249	28169	28090	28011	27933	27855
3·6	27778	27701	27624	27548	27473	27397	27322	27248	27174	27100
3·7	27027	26954	26882	26810	26738	26667	26596	26525	26455	26385
3·8	26316	26247	26178	26110	26042	25974	25907	25840	25773	25707
3·9	25641	25575	25510	25445	25381	25316	25253	25189	25126	25063
4·0	25000	24938	24876	24814	24752	24691	24631	24570	24510	24450
4·1	24390	24331	24272	24213	24155	24096	24038	23981	23923	23866
4·2	23810	23753	23697	23641	23585	23529	23474	23419	23364	23310
4·3	23256	23202	23148	23095	23041	22989	22936	22883	22831	22779
4·4	22727	22676	22624	22573	22523	22472	22422	22371	22321	22272
4·5	22222	22173	22124	22075	22026	21978	21930	21882	21834	21786
4·6	21739	21692	21645	21598	21552	21505	21459	21413	21368	21322
4·7	21277	21231	21186	21142	21097	21053	21008	20964	20921	20877
4·8	20833	20790	20747	20704	20661	20619	20576	20534	20492	20450
4·9	20408	20367	20325	20284	20243	20202	20161	20121	20080	20040
5·0	20000	19960	19920	19881	19841	19802	19763	19724	19685	19646
5·1	19608	19569	19531	19493	19455	19417	19380	19342	19305	19268
5·2	19231	19194	19157	19120	19084	19048	19011	18975	18939	18904
5·3	18868	18832	18797	18762	18727	18692	18657	18622	18587	18553
5·4	18519	18484	18450	18416	18382	18349	18315	18282	18248	18215
	0	1	2	3	4	5	6	7	8	9

PROPORTIONAL PARTS OF MEAN DIFFERENCES

	1	2	3	4	5	6	7	8	9
1·0									
1·1									
1·2									
1·3									
1·4									
1·5	42	83	125	167	209	250	292	334	375
1·6	37	74	110	147	184	221	258	294	331
1·7	33	65	98	131	164	196	229	262	294
1·8	29	58	88	117	146	175	204	234	263
1·9	26	53	79	105	132	158	184	210	237
2·0	24	48	71	95	119	143	167	190	214
2·1	22	43	65	86	108	130	151	173	194
2·2	20	40	59	79	99	119	139	158	178
2·3	18	36	54	72	91	109	127	145	163
2·4	17	33	50	67	84	100	117	134	150
2·5	15	31	46	62	77	92	108	123	139
2·6	14	29	43	57	72	86	100	114	129
2·7	13	26	40	53	66	79	92	106	119
2·8	12	25	37	49	62	74	86	98	111
2·9	12	23	35	46	58	69	81	92	104
3·0	11	22	32	43	54	65	76	86	97
3·1	10	20	30	40	51	61	71	81	91
3·2	10	19	29	38	48	57	67	76	86
3·3	9	18	27	36	45	53	62	71	80
3·4	8	17	25	34	42	50	59	67	76
3·5	8	16	24	32	40	47	55	63	71
3·6	8	15	23	30	38	45	53	60	68
3·7	7	14	21	28	36	43	50	57	64
3·8	7	14	20	27	34	41	48	54	61
3·9	6	13	19	26	32	38	45	51	58
4·0	6	12	18	24	31	37	43	49	55
4·1	6	12	17	23	29	35	41	46	52
4·2	6	11	17	22	28	33	39	44	50
4·3	5	11	16	21	27	32	37	42	48
4·4	5	10	15	20	26	31	36	41	46
4·5	5	10	14	19	24	29	34	38	43
4·6	5	9	14	18	23	28	32	37	41
4·7	4	9	13	18	22	26	31	35	40
4·8	4	9	13	17	22	26	30	34	39
4·9	4	8	12	16	20	25	29	33	37
5·0	4	8	12	16	20	24	27	31	35
5·1	4	8	11	15	19	23	26	30	34
5·2	4	7	11	15	18	22	25	29	33
5·3	3	7	10	14	18	21	24	28	31
5·4	3	7	10	14	17	20	24	27	30
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5·5	18182	18149	18116	18083	18051	18018	17986	17953	17921	17889
5·6	17857	17825	17794	17762	17731	17699	17668	17637	17606	17575
5·7	17544	17513	17483	17452	17422	17391	17361	17331	17301	17271
5·8	17241	17212	17182	17153	17123	17094	17065	17036	17007	16978
5·9	16949	16920	16892	16863	16835	16807	16779	16750	16722	16694
6·0	16667	16639	16611	16584	16556	16529	16502	16474	16447	16420
6·1	16393	16367	16340	16313	16287	16260	16234	16207	16181	16155
6·2	16129	16103	16077	16051	16026	16000	15974	15949	15924	15898
6·3	15873	15848	15823	15798	15773	15748	15723	15699	15674	15649
6·4	15625	15601	15576	15552	15528	15504	15480	15456	15432	15408
6·5	15385	15361	15337	15314	15291	15267	15244	15221	15198	15175
6·6	15152	15129	15106	15083	15060	15038	15015	14993	14970	14948
6·7	14925	14903	14881	14859	14837	14815	14793	14771	14749	14728
6·8	14706	14684	14663	14641	14620	14599	14577	14556	14535	14514
6·9	14493	14472	14451	14430	14409	14388	14368	14347	14327	14306
7·0	14286	14265	14245	14225	14205	14184	14164	14144	14124	14104
7·1	14085	14065	14045	14025	14006	13986	13966	13947	13928	13908
7·2	13889	13870	13850	13831	13812	13793	13774	13755	13736	13717
7·3	13699	13680	13661	13643	13624	13605	13587	13569	13550	13532
7·4	13514	13495	13477	13459	13441	13423	13405	13387	13369	13351
7·5	13333	13316	13298	13280	13263	13245	13228	13210	13193	13175
7·6	13158	13141	13123	13106	13089	13072	13055	13038	13021	13004
7·7	12987	12970	12953	12937	12920	12903	12887	12870	12853	12837
7·8	12821	12804	12788	12771	12755	12739	12723	12706	12690	12674
7·9	12658	12642	12626	12610	12594	12579	12563	12547	12531	12516
8·0	12500	12484	12469	12453	12438	12422	12407	12392	12376	12361
8·1	12346	12330	12315	12300	12285	12270	12255	12240	12225	12210
8·2	12195	12180	12165	12151	12136	12121	12107	12092	12077	12063
8·3	12048	12034	12019	12005	11990	11976	11962	11947	11933	11919
8·4	11905	11891	11876	11862	11848	11834	11820	11806	11792	11779
8·5	11765	11751	11737	11723	11710	11696	11682	11669	11655	11641
8·6	11628	11614	11601	11587	11574	11561	11547	11534	11521	11507
8·7	11494	11481	11468	11455	11442	11429	11416	11403	11390	11377
8·8	11364	11351	11338	11325	11312	11299	11287	11274	11261	11249
8·9	11236	11223	11211	11198	11186	11173	11161	11148	11136	11123
9·0	11111	11099	11086	11074	11062	11050	11038	11025	11013	11001
9·1	10989	10977	10965	10953	10941	10929	10917	10905	10893	10881
9·2	10870	10858	10846	10834	10823	10811	10799	10787	10776	10764
9·3	10753	10741	10730	10718	10707	10695	10684	10672	10661	10650
9·4	10638	10627	10616	10604	10593	10582	10571	10560	10549	10537
9·5	10526	10515	10504	10493	10482	10471	10460	10449	10438	10428
9·6	10417	10406	10395	10384	10373	10363	10352	10341	10331	10320
9·7	10309	10299	10288	10277	10267	10256	10246	10235	10225	10215
9·8	10204	10194	10183	10173	10163	10152	10142	10132	10121	10111
9·9	10101	10091	10081	10070	10060	10050	10040	10030	10020	10010
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8·9	1	3	4	5	6	8	9	10	11
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9·3	1	2	4	5	6	7	8	9	10
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9·5	1	2	3	4	5	7	8	9	10
9·6	1	2	3	4	5	6	8	9	10
9·7	1	2	3	4	5	6	7	8	10
9·8	1	2	3	4	5	6	7	8	9
9·9	1	2	3	4	5	6	7	8	9
	1	2	3	4	5	6	7	8	9

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